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Modifications to Gate-Flume Structures on the Weber Davis Canal

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M. Leon Hyatt

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MODIFICATIONS TO GATE-FLUME STRUCTURES
ON THE WEBER-DAVIS CANAL

Prepared for

Utah State Department of Highways

In cooperation with

U. S. Bureau of Public Roads
Davis and Weber Counties Canal Company
West Branch Irrigation Company
West Layton Irrigation Company

Project Number: I-15-7(41)331

Project Name: Layton to Roy--Parshall Flume Curves

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Logan, Utah

February 1966

Report PR-WG24-4

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with representatives of the Utah State Department of Highways and the Davis and Weber Counties Canal Company. Mr. Ward Dean Morby and Mr. Dean Sutton have represented the Highway Department, whereas the Canal Company has been represented by Mr. Earl Harris, Mr.

Herbert Barnes, and Mr. Blaine Johnson. The efforts of Mr. Morby in getting the study underway and Mr. Harris, who made a number of trips to Logan to review the progress of the work, are especially

appreciated.

The construction of the laboratory structure was under the

direction of Mr. Kenneth Steele with Messrs. Verle Bindrup, Gilbert Peterson, and Mark Nilson participating. Much of the laboratory

testing was accomplished by Messrs. Raymond Johnson, Keith Eggleston, and Lloyd Austin. The design of the cover, along with the preparation of the drawings, is the result of the creative efforts of Mr. Joe D.

England.

Gaylord V. Skogerboe
M. Leon Hyatt

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MODIFICATIONS TO GATE-FLUME STRUCTURES

ON THE WEBER-DAVIS CANAL

Present Structures

The turnout structures under study divert flows from the Weber-Davis Canal near Clearfield, Utah. A portion of the canal in this area was realigned as a result of the construction of the Interstate Highway System. The twin turnout structures, used to divert water to the West Branch Irrigation Company and West Layton Irrigation Company, were constructed in conjunction with the realignment of the concrete-lined canal.

A three-dimensional drawing of the twin turnout structures is shown in Fig. 1. Water is diverted from the canal by passing under the gates which are 72 inches wide by 48 inches high (Fig. 2). The maximum discharge diverted through each of the structures is approximately 35 cfs (cubic feet per second, or second-feet). To properly allocate and assess the quantity of flow delivered to each of the irrigation companies, Parshall flumes having a throat width of four feet and a depth of four feet were placed inside each structure. After passing through the Parshall flumes, the water is conveyed by twin corrugated metal arch pipelines, located under the newly constructed freeway, to existing irrigation distribution systems which serve lands west of the highway. A portion of the twin turnout structures are covered with concrete

(Fig. 3) to accommodate the service road located on the west side of the canal.

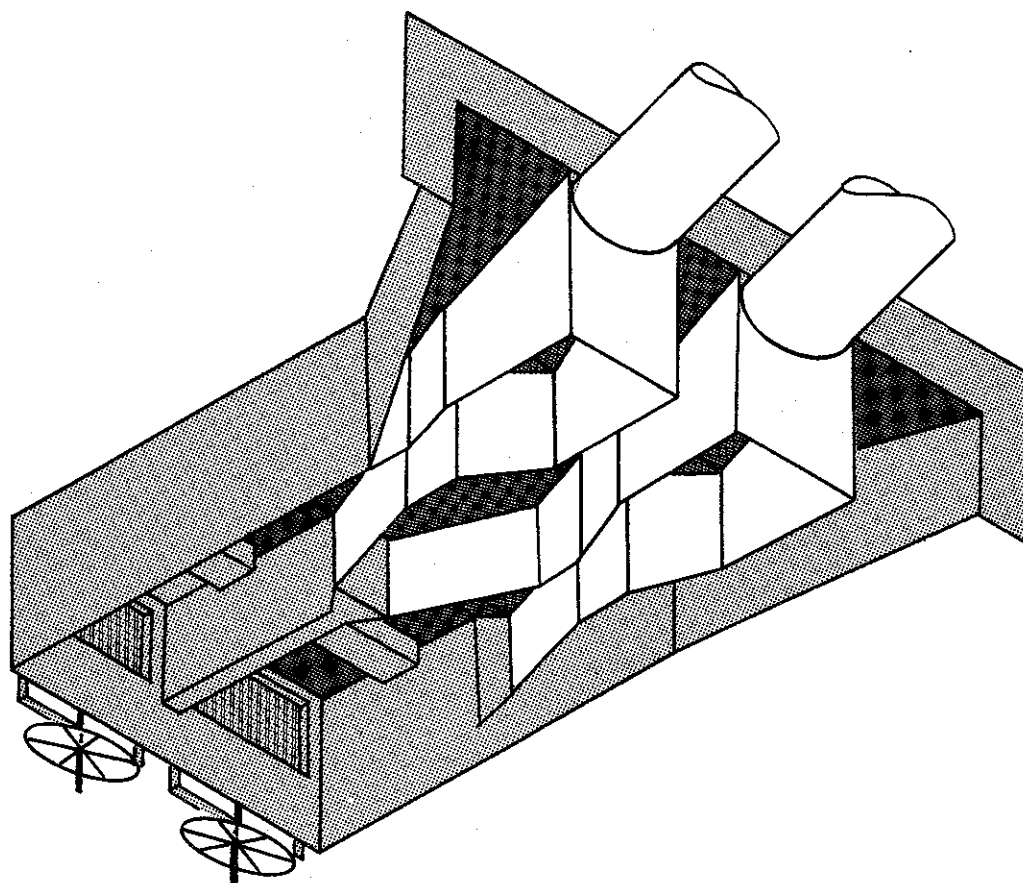


Figure 1. Isometric of twin turnout structures.

Figure 3. Outlet of turnout structures with Weber-Davis Canal in background.

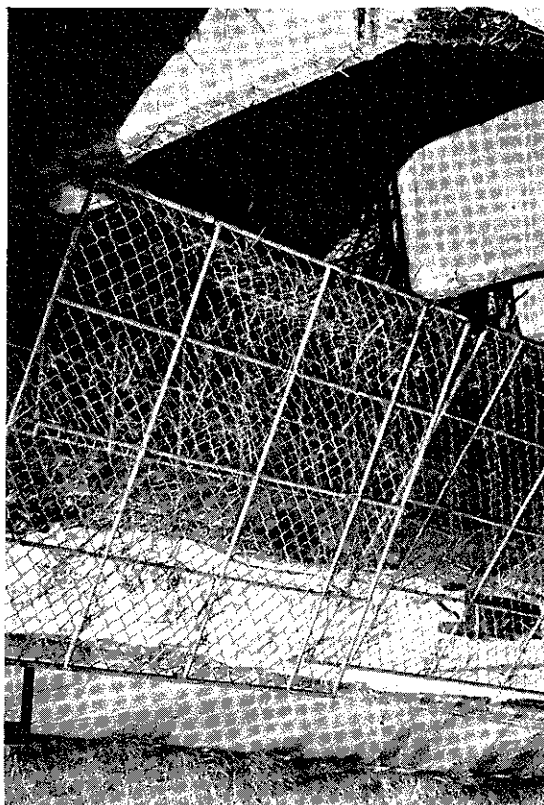


Figure 4. Stilling float located inside turnout structure.

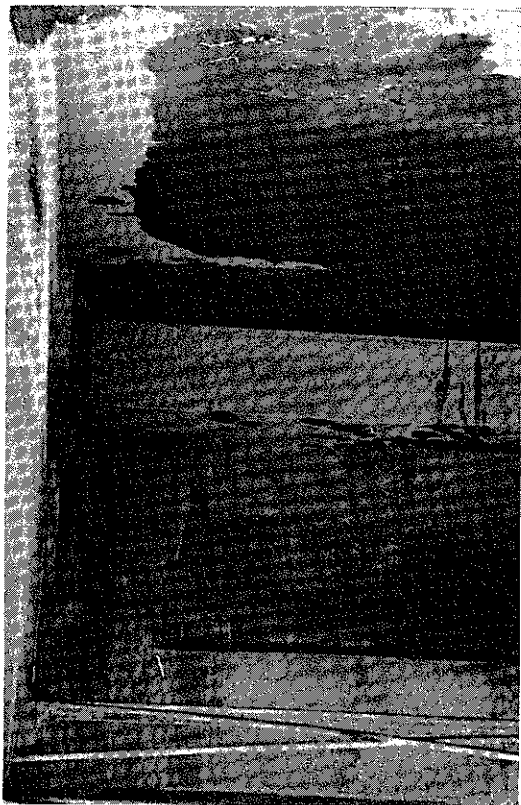


Figure 2. Slide gates at inlet to twin turnout structures.



One of the difficulties encountered in the design of the structures

was the space available between the canal and the cut bank on the freeway right-of-way. This space limitation resulted in the entrance of the four-foot Parshall flume being located less than nine feet away from the diversion gate. The situation was further aggravated by placing the lip of the gate opening two feet lower than the bottom of the canal. The net result was a high velocity jet passing under the gate with maximum velocities reaching 15 feet per second. The high velocity jet resulted in considerable turbulence and wave action within the structure. The instability of the flow created concern regarding the reliability of the standard calibration for Parshall flumes in predicting the actual flow being diverted to each of the two irrigation companies. In an effort to reduce the height of waves, a metal stilling float was placed in each structure (Fig. 4).

The floats did not materially improve the flow conditions.

Laboratory Structure

The high velocities and instability of the flow precluded the use of a current meter to adequately check the accuracy of the flow rate measurements in the prototype field structures. Consequently, the construction of a similar structure in the laboratory was proposed in order to check the flow measurement accuracy of the present structures, and to study possible structural modifications to improve the flow conditions.

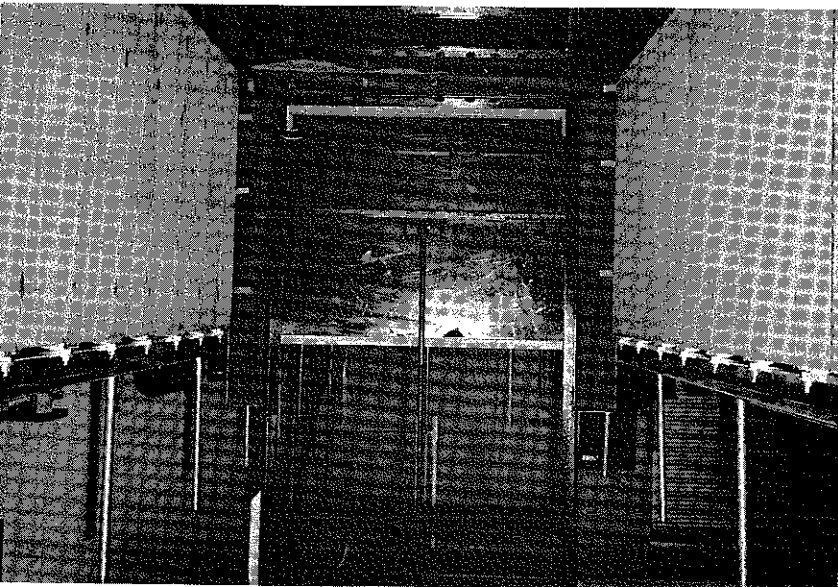


Figure 5. Slide gate at inlet to laboratory structure.

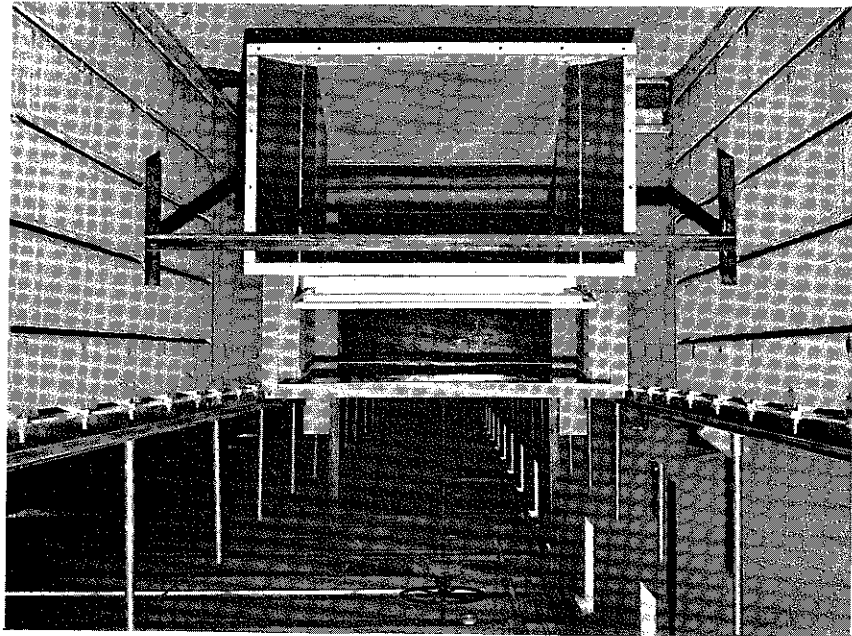
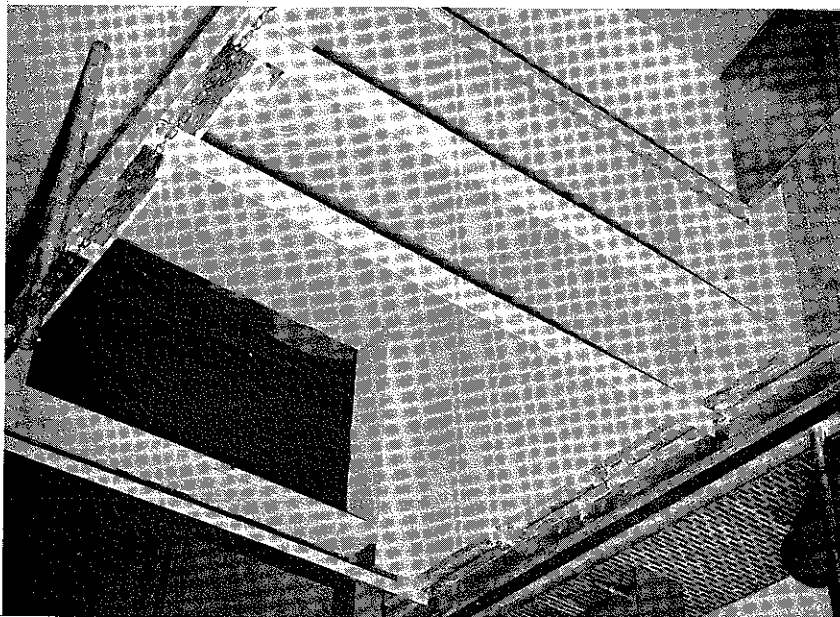


Figure 6. Turnout structure constructed in laboratory (looking upstream).

Figure 8. Close-up of gate and headwall.



Figure 7. Top view of box between gate and Parshall flume.



The recent completion of the Utah Water Research Laboratory

with its large flume, which is 8 feet wide, 6 feet deep, and has a flow capacity of approximately 200 cfs, provided a facility allowing the construction of a full-scale structure in the laboratory. The laboratory reproduction of the field turnout structures is illustrated in Figs. 5, 6, 7, and 8. Since each of the field structures are identical except for a small difference in the elevation of the Parshall flume inlet floors, only one structure had to be constructed in the laboratory. Critical depth occurs in the Parshall flume near the flume crest and a change in flow conditions downstream from the flume crest does not affect flow conditions upstream from the flume crest. Consequently, it was not necessary to reconstruct any portion of the structure downstream from the Parshall flume.

Initial tests were conducted to evaluate the flow measurement accuracy of the existing structures. Figs. 9 and 10 portray the flow conditions at a discharge of 30 cfs. The depth of flow upstream from the gate in Figs. 9 and 10 is comparable to the maximum water surface elevation in the Weber-Davis Canal at the location of the turnout structures. A comparison of actual laboratory tests with the standard rating for a four-foot Parshall flume disclosed that the field readings were about 10 percent low at 10 cfs and 20 percent low at 30 cfs.

Figure 11. Close-up of rough water surface immediately downstream from the gate.

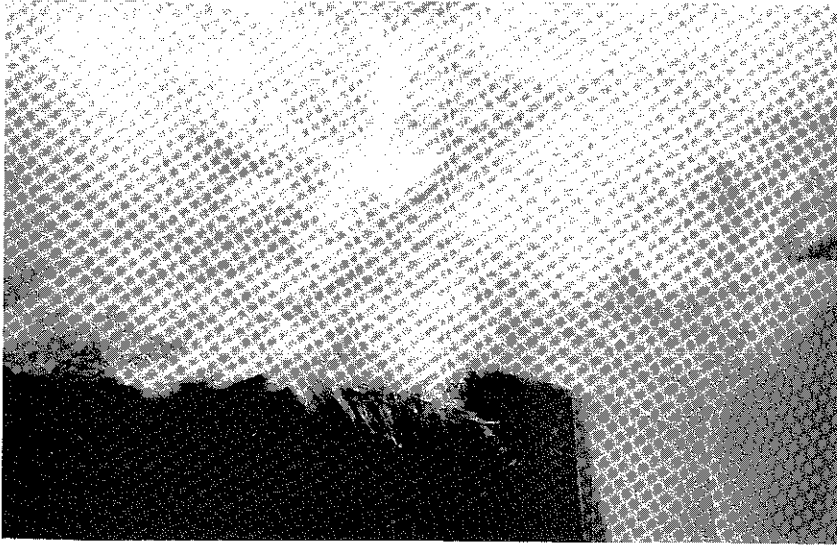
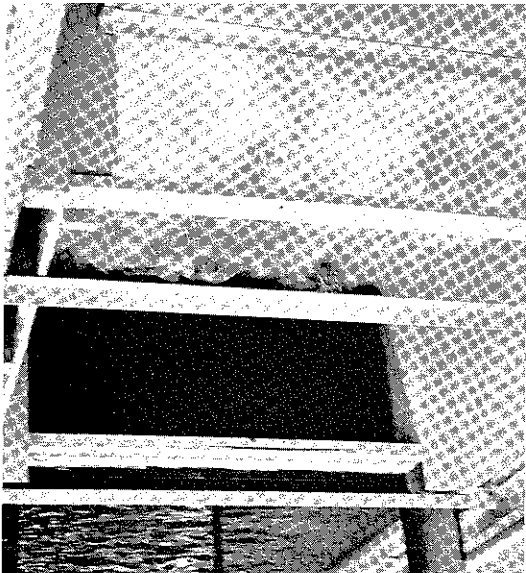


Figure 9. Discharge of 30 cfs through laboratory structure.



Figure 10. Roughness of water surface with no modifications.



Modifications Studied

As previously described, the flow conditions in the existing structure necessitated breaking up the water jet flowing under the gate. By breaking up the water jet it was believed that flow conditions could be established which would provide a more nearly uniform velocity distribution entering the Parshall flume with a consequent improvement in flow measurement accuracy.

The first attempt made to break up the water jet under the gate was the placement of five blocks in two rows (Figs. 12 and 14). The blocks used were 18 inches high, 12 inches wide, and 2 inches deep. As shown in Fig. 12, the first row, consisting of three blocks, was placed 2 feet downstream from the gate sill and with a spacing width 12 inches between blocks. A width of 12 inches was used because of the geometry of the gate opening and to keep the number of blocks to a minimum. The second row of blocks was placed 12 inches behind the first row and staggered so as to intercept and break up the flow which passed between the blocks in the first row. Figs. 15 and 16 show the flow conditions at 35 cfs when using the block arrangement. As can be seen from the turbulence and boils of the water in Fig. 15, the blocks are very effective in destroying the kinetic energy of the high velocity jet. Despite breaking up the water jet, a great amount of turbulence still existed as the flow entered the Parshall flume, thereby causing some fluctuation in the upstream depth of flow, or

H_a gage reading.

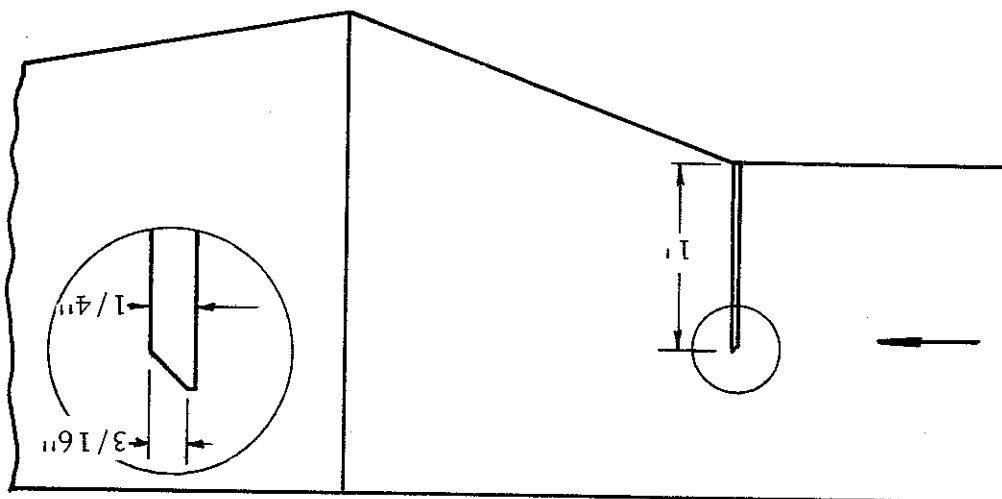


Figure 12. Location of 2' x 12' x 18' blocks.

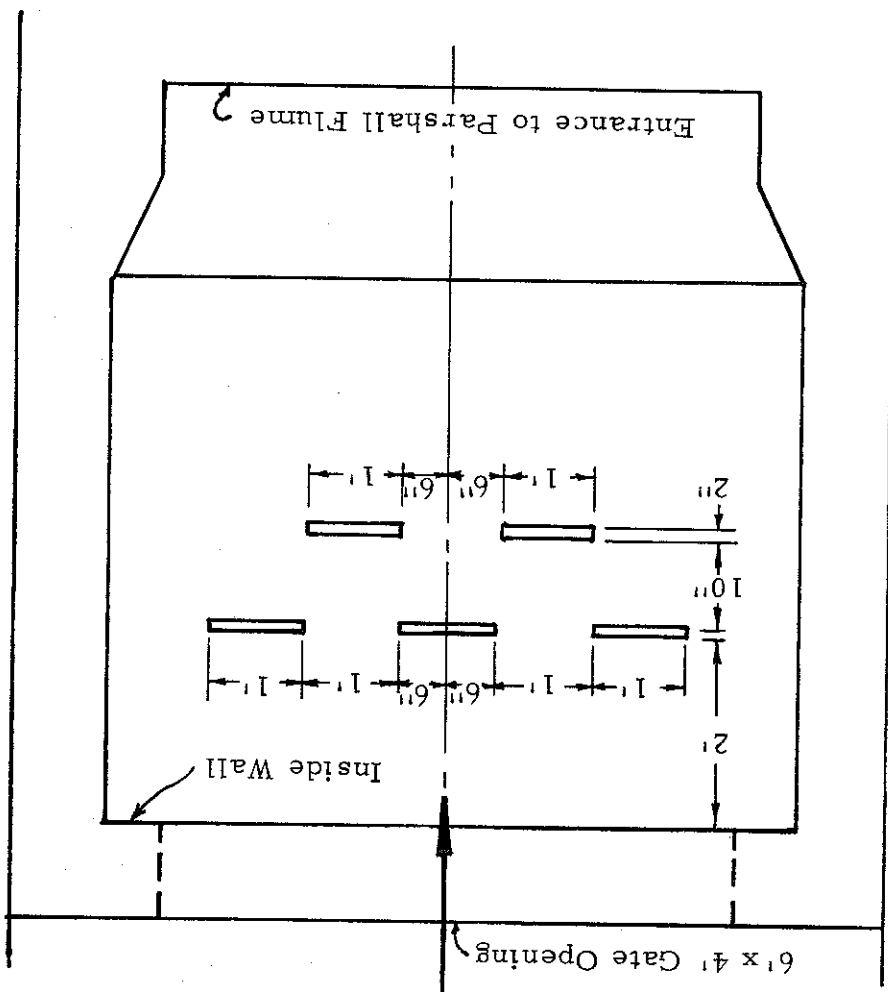


Figure 13. Location of weir plate.

Figure 14. Two rows of 2"x 12"x 18" blocks.

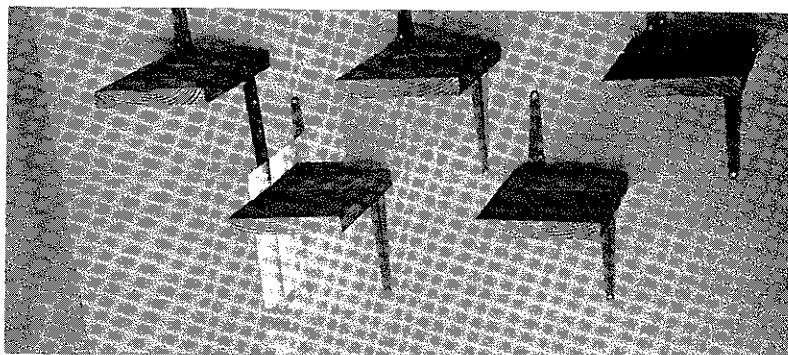


Figure 15. Flow conditions over the blocks showing upstream water surface level.

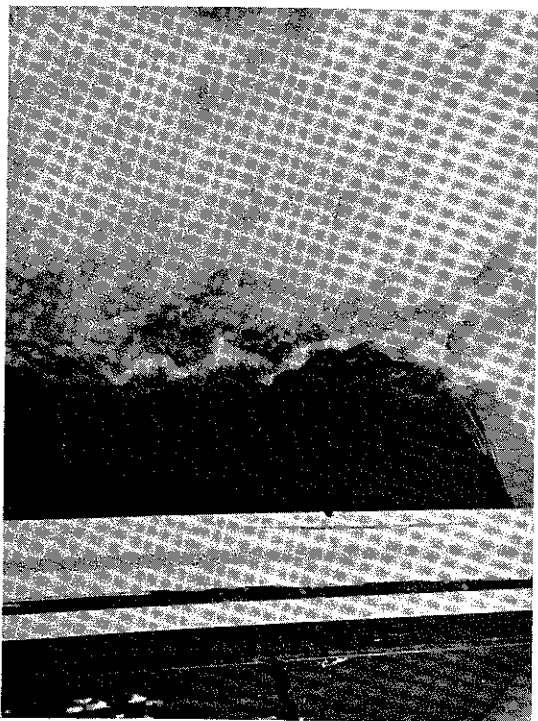
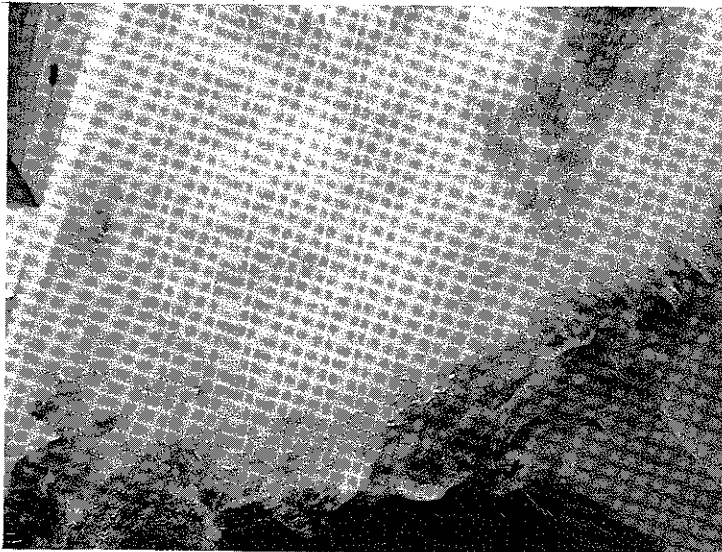


Figure 16. Flow conditions over the blocks at discharge of 35 cfs.



Although the flow conditions with the blocks in place were much better than the flow conditions which prevail in the existing structures, it was still desirable to reduce the intensity of turbulence entering the Parshall flume to enable a more accurate gage reading. A weir plate was installed at the crest of the Parshall flume to further reduce the degree of turbulence. The sharp-crested weir plate was 12 inches high and 4 feet long, which corresponds with the throat width of the Parshall flume (Figs. 13 and 17). The objective in using the weir plate was to increase the depth of flow over the blocks. The increased flow depth not only assists in dissipating the energy from the high velocity jet, but also requires larger gate openings with a corresponding decrease in the velocity of the jet passing under the gate. The weir plate was effective in accomplishing its intended objectives. Fig. 18 shows a flow of 30 cfs passing through the turnout structure and illustrates the improved flow conditions with the addition of the weir plate.

The possibility of improving flow conditions by deflecting the water jet in an upward direction immediately after passing under the gate was considered. The objective in deflecting the jet would be to shorten the length of basin required to dissipate the kinetic energy of the jet. To deflect the water jet as it left the gate, an inclined sill was constructed on a 45° angle with the inclination beginning at a distance of 3 inches downstream from the gate. The width of the sill was 6 feet to correspond with the width of the gate opening, and the height of the sill was 9 inches

Figure 18. Flow conditions over 2"x 12"x 18" blocks with weir plate installed and a discharge of 30 cfs.

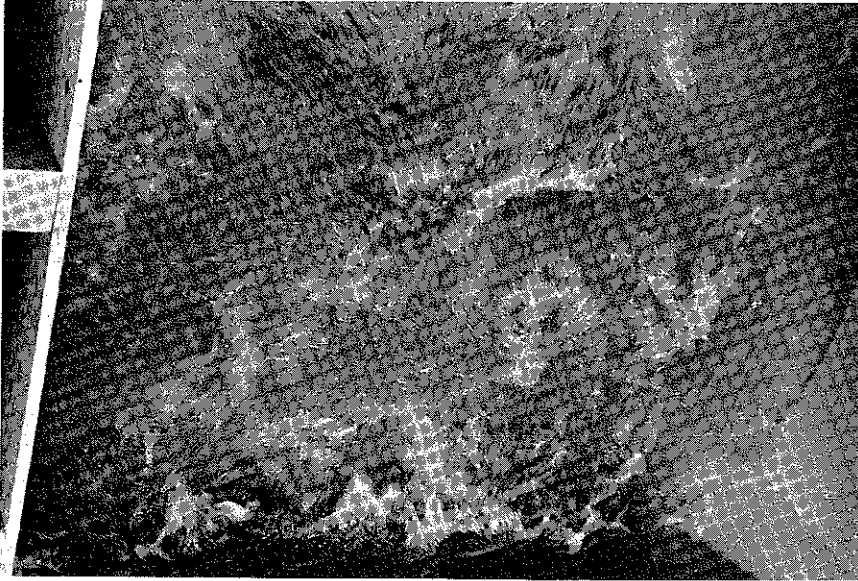
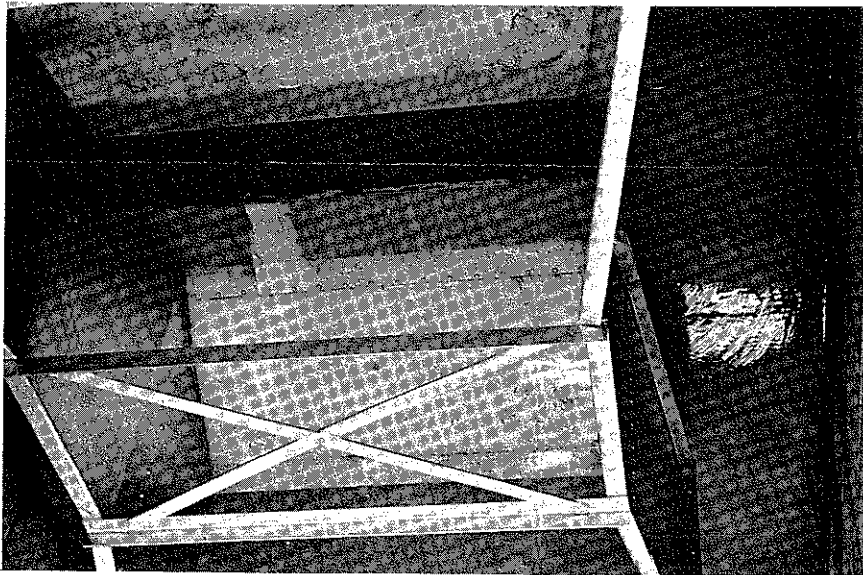


Figure 17. Weir plate placed at Parshall flume crest.



(Fig. 19). Figs. 20 and 21 show the flow conditions occurring in the

turnout structure at a flow rate of 30 cfs with the inclined sill being

used in conjunction with the blocks and weir plate. The inclined sill

was very effective in dissipating energy (Fig. 21), but the intensity of

turbulence entering the Parshall flume was not as satisfactory as with

the blocks alone (Fig. 18). The joint use of the inclined sill and blocks

required that the blocks be moved further downstream for maximum

effectiveness. Because of the short basin length, moving the blocks

further downstream aggravated the flow conditions entering the Parshall

flume.

In an effort to reduce the height of the water surface waves, a

wave suppressor fixed in position was used. The wave suppressor was

a 5/8-inch piece of plywood 7 feet 2 inches wide and 4 feet long. For

strength, two 2 x 4's were placed on the top of the wave suppressor.

The first flow tests were made utilizing the wave suppressor in con-

junction with the inclined sill, blocks, and weir plate. The results

were not favorable (Figs. 22 and 23), but by removing the inclined sill

very satisfactory flow conditions were obtained. The situation was

further improved by optimizing the vertical location of the wave sup-

pressor. Figs. 24 and 25 show the flow conditions which existed for

a flow rate of 30 cfs utilizing the wave suppressor, blocks, and weir

plate. The water, after passing under the gate and striking the blocks,

was thrust upward hitting the wave suppressor which in turn dampened

the height of the waves. The turbulence and wave height immediately

Figure 20. Flow conditions with inclined sill, blocks, and weir plate at discharge of 30 cfs.

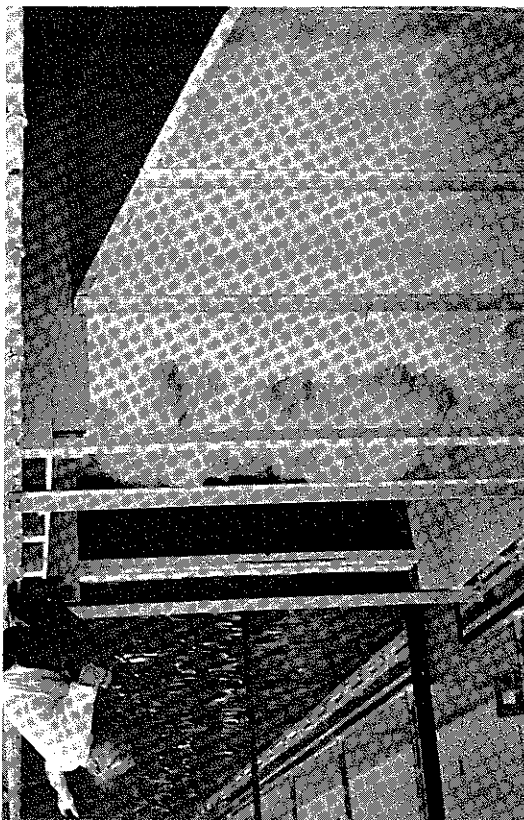


Figure 21. Close-up of boil occurring over blocks created by inclined sill and with weir plate in place.

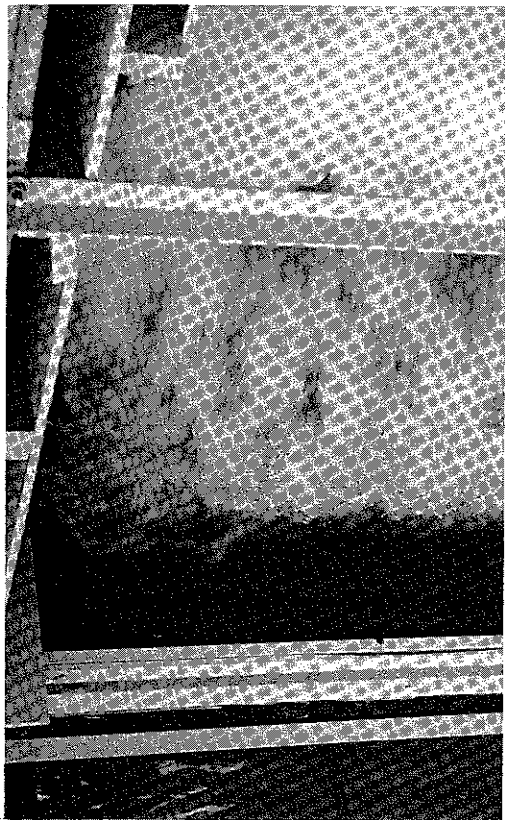


Figure 19. Inclined sill placed on bottom of gate opening.

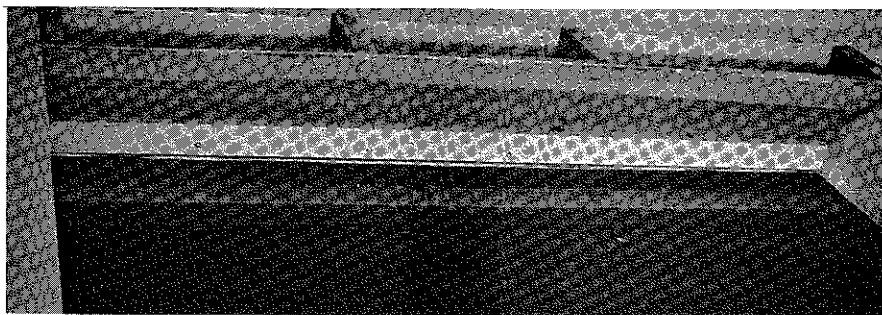


Figure 22. Installation of inclined sill, blocks, and wave suppressor.

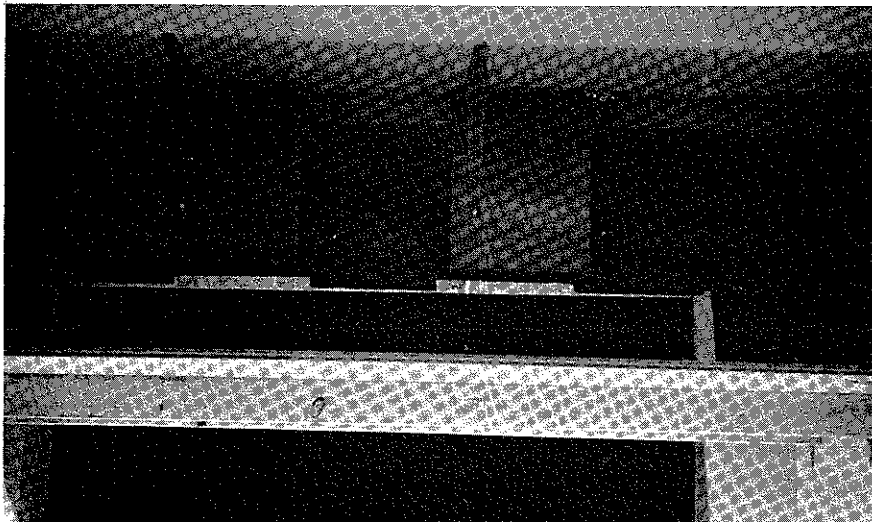


Figure 23. Flow conditions at exit of blocks and wave suppressor with inclined sill and weir plate in place.

Figure 24. Flow conditions with 2"x12"x18" blocks, wave suppressor, and weir plate at discharge of 30 cfs.

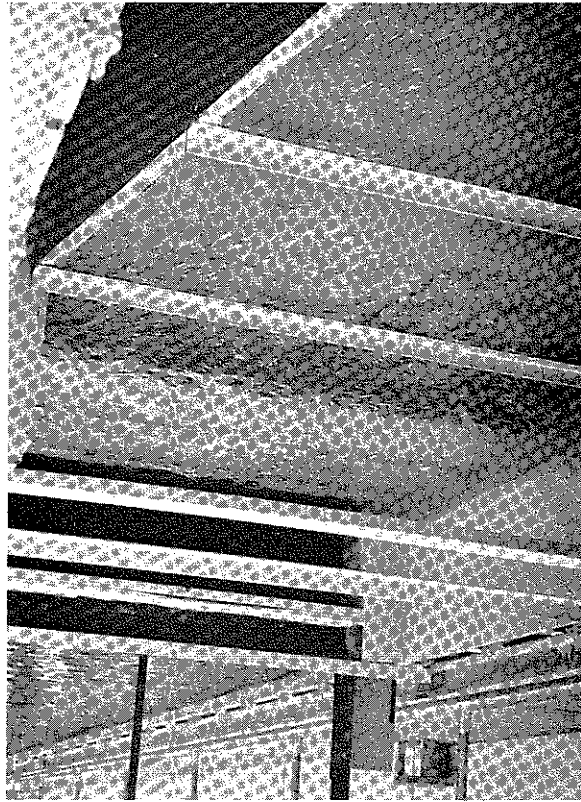
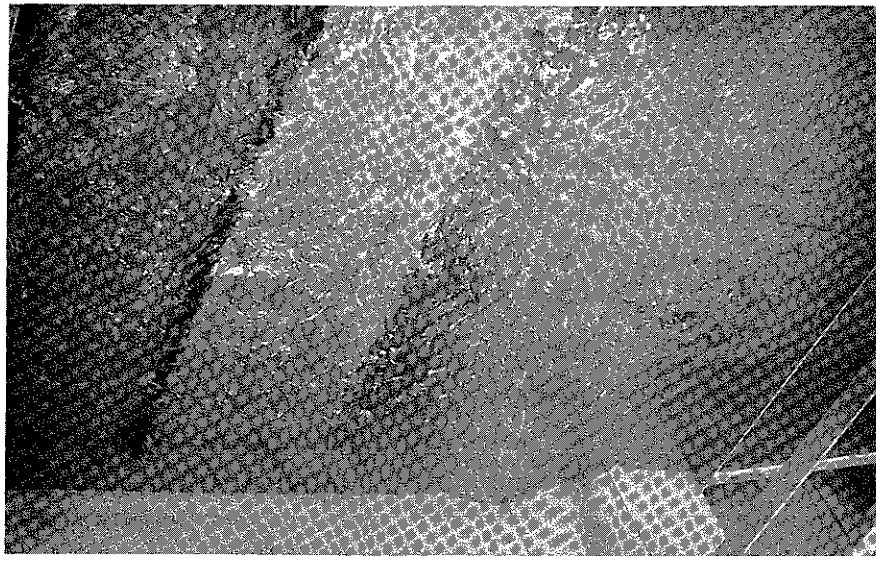


Figure 25. Flow conditions between headwall and Parshall flume with blocks, wave suppressor, and weir plate.



downstream from the blocks was improved considerably compared with any previous physical arrangement of appurtenances. The flow conditions entering the Parshall flume were very satisfactory with almost no fluctuations of the water surface (Fig. 26).

Further testing utilizing various combinations of the weir plate, wave suppressor, and blocks did not yield improved results, and in most cases the flow situation was aggravated. Tests were conducted with the wave suppressor located at various horizontal and vertical positions with no improvement in results. Additional testing regarding the placement of the blocks created flow conditions which were generally not as satisfactory as the initial arrangement. Tests with blocks only 12 inches high resulted in a definite decrease in energy dissipation.

Proposed Modifications

One of the guidelines that should be used in the construction of the proposed modifications would be ease of construction, removability, and replacement. For these reasons, steel construction is proposed.

Floor Blocks

Fig. 30 lists the details of the proposed construction of the floor

blocks. Essentially, the two rows of blocks would be welded to a

34"x 64" steel plate and the plate would in turn be bolted to the concrete

floor.

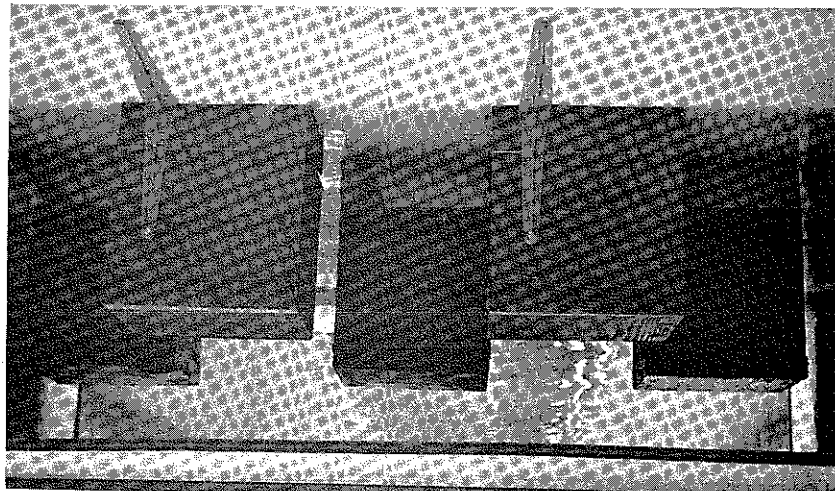


Figure 26. Wave suppressor and 9' x 12' x 18' blocks (looking upstream).

Figure 27. Wave suppressor and blocks with weir plate in background (looking downstream).

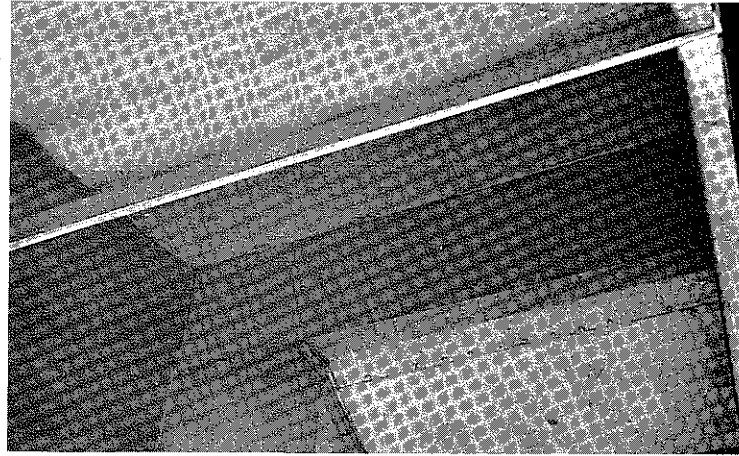
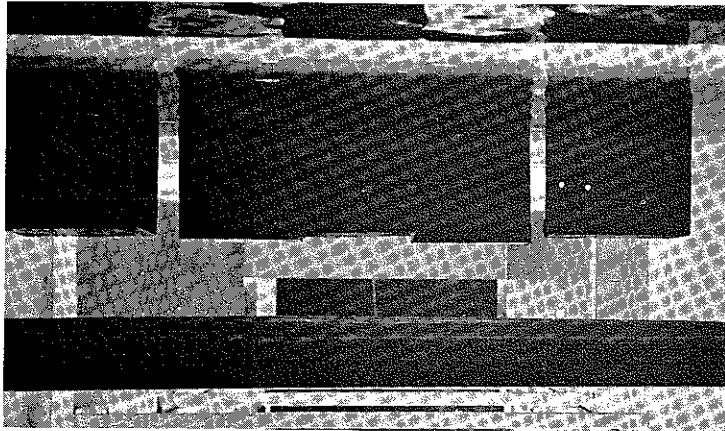


Figure 28. Weir plate (12' high) located at Parshall flume crest.

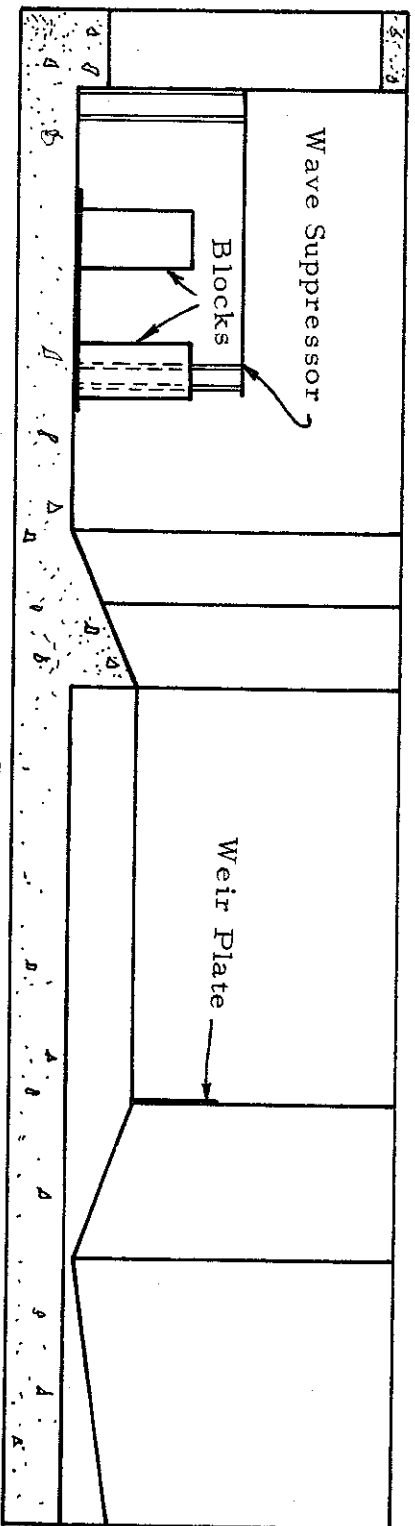
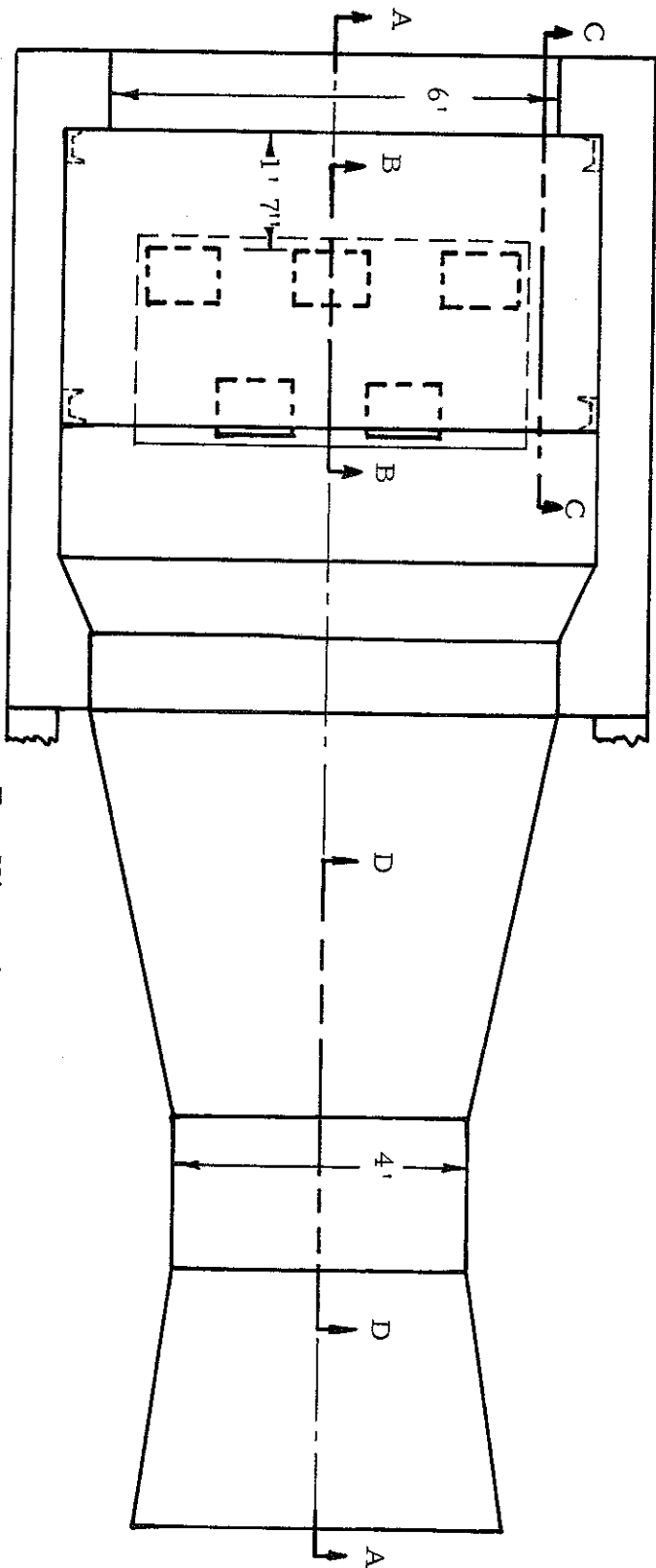


Figure 29. Gate-flume turnout structure with proposed modifications.

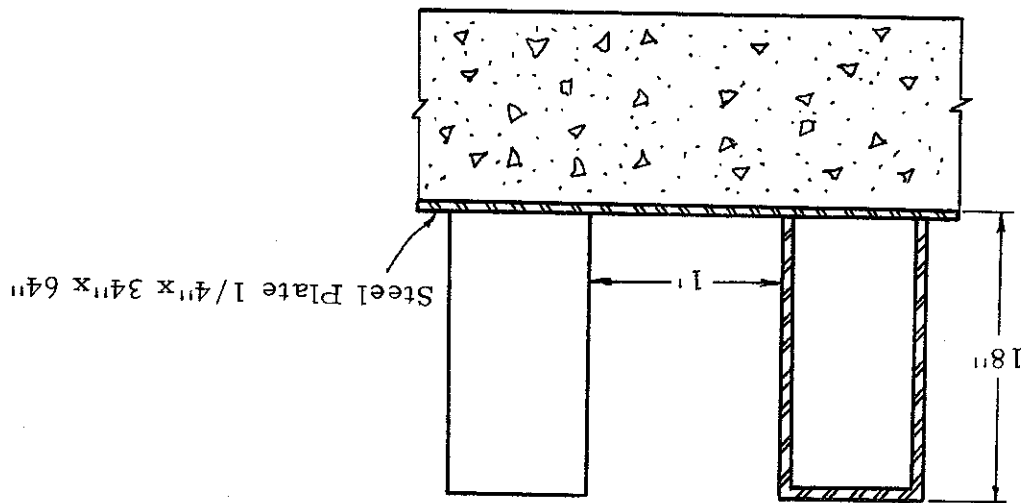
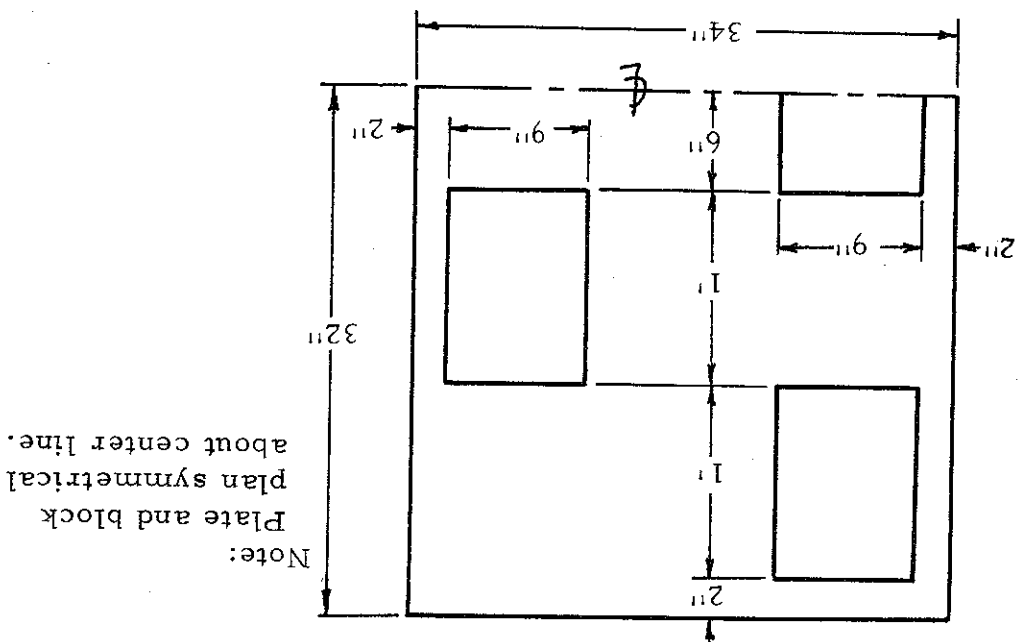


Figure 30. Details of floor blocks.

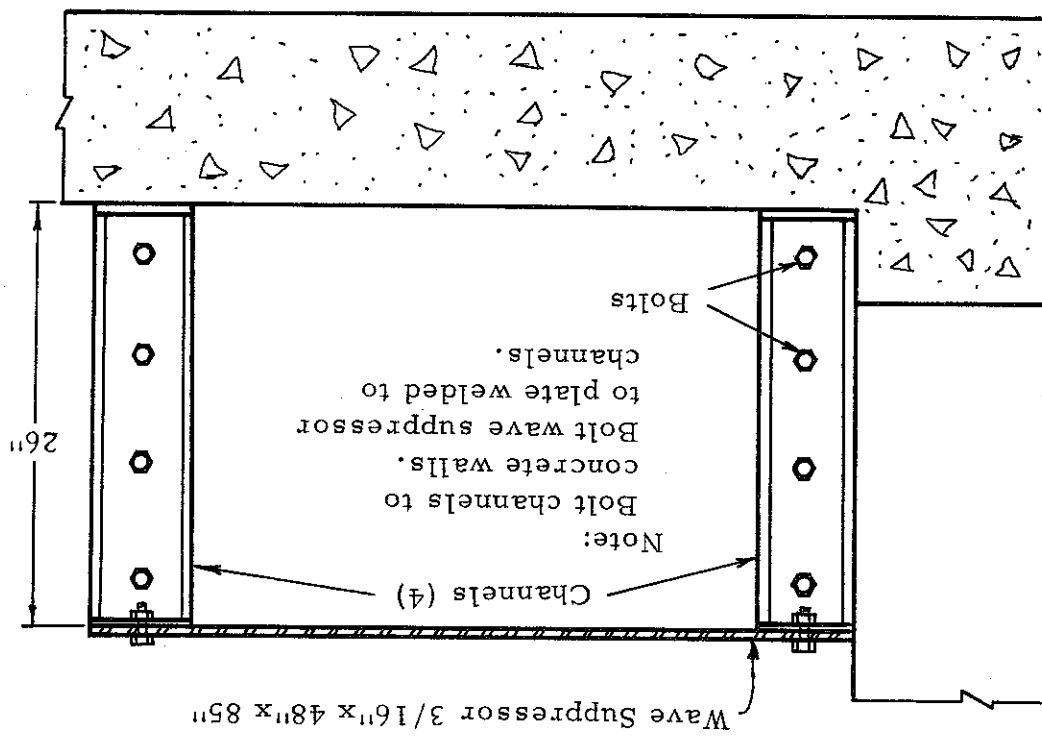
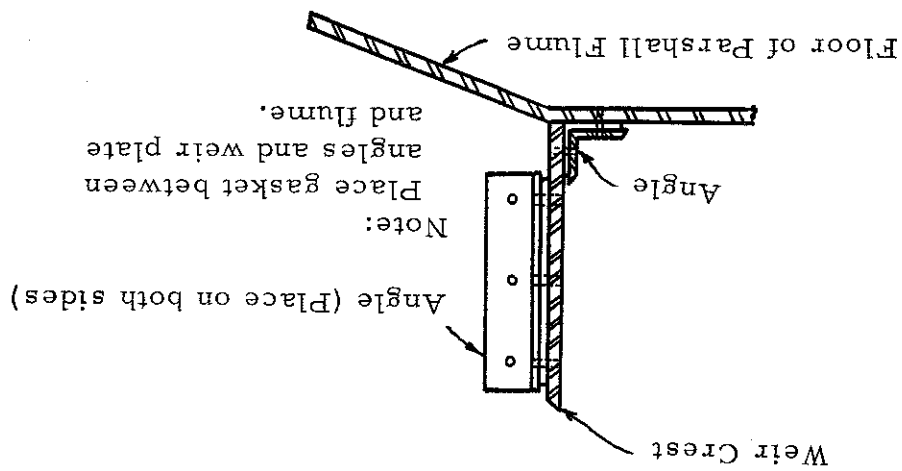
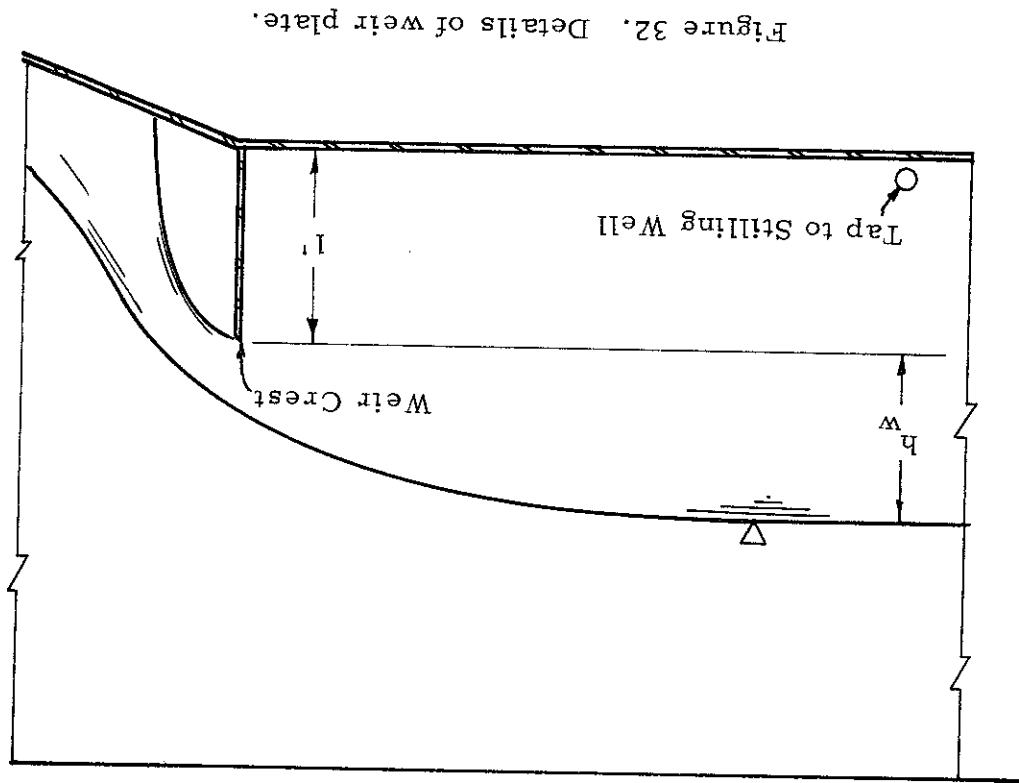


Figure 31. Details of wave suppressor.



Wave Suppressor

The wave suppressor would consist of a 3/16"x4"x71/2" steel plate bolted to the top of four channel columns. The columns would be located under each corner of the wave suppressor and would be bolted to the existing concrete walls. Hooks placed on the top side of the wave suppressor would facilitate its removal from the turnout structure. Construction details for the wave suppressor are given in Fig. 31.

Weir Plate

The details of the weir plate (Fig. 32) consist primarily of a 1/4"x12"x48" steel plate held in place by angles connected to the floor and sides of the steel Parshall flume. The angles would be fastened to the flume in such a manner that they could also be removed. An opening with a cap should be placed near the bottom of the weir plate to facilitate draining the turnout structures. New gages would be installed in the stilling wells with the zero point of each gage being placed at the same elevation as the crest of the weir plate. There is a difference in elevation of the Parshall flume crests in the existing structures. Consequently, the crest elevation of the two weir plates will differ by a like amount, as will the zero points of the gages used to measure the depth of flow over the weir crest.

Stilling Floats

The stilling floats presently being used in the turnout structures (Fig. 4) should be removed. Their use is no longer necessary once the proposed modifications have been constructed and installed.

Flow Rate Calibrations

Calibration curves and tables have been prepared for the turnout structures based on the proposed modifications. The placement of the blocks and other modifications may create a condition whereby trash, particularly long objects, might collect among the blocks or between the blocks and gate. If this should occur, the wave suppressor would hamper efforts to remove the trash. Also, the water users have indicated an interest in being able to utilize the turnout structures without the weir plate. Hence, to insure that the turnout structures can be used as satisfactory flow measuring devices under any possible circumstance, flow rate calibrations have been prepared for the following combinations of modifications: (1) blocks, weir plate, and wave suppressor; (2) blocks and weir plate; (3) blocks and wave suppressor; and (4) blocks alone. Should future circumstances show the wave suppressor or weir plate to be a problem, either or both could be removed and the turnout structure would still be capable of serving its dual function as a diversion structure and a flow measurement structure.

The calibration curve with the blocks, wave suppressor, and weir plate is shown in Fig. 33. The average deviation of the laboratory measurements from the straight line plot in Fig. 33 is 0.75 percent. Since the accuracy of the device used in the laboratory to measure the discharge is approximately 1 percent, the average error in determining the flow rate in the field based on staff gage readings

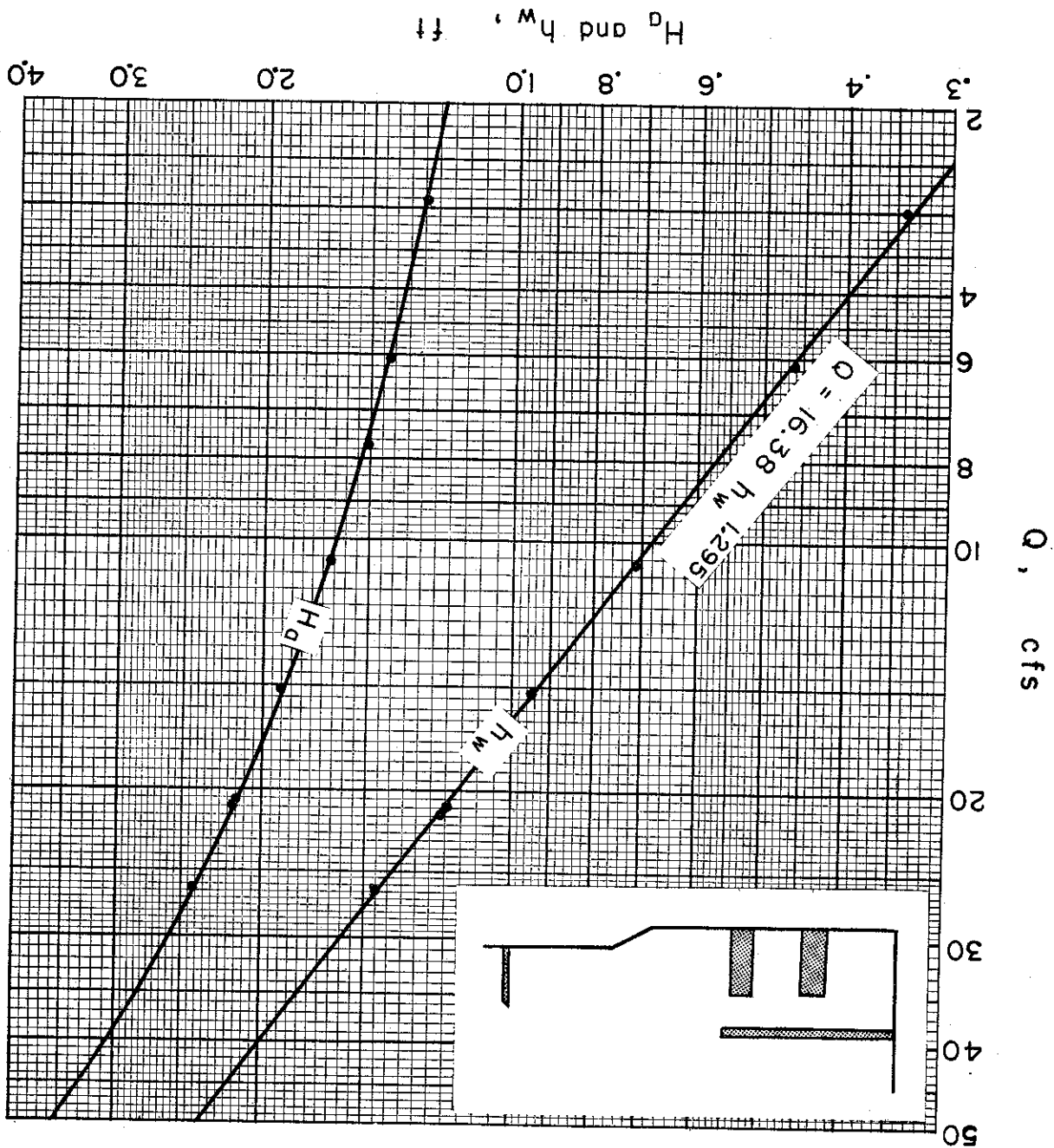


Table 1. Rating with blocks, wave suppressor, and weir plate.

0.64		9.19	0.99	16.17	1.34	23.93	1.69	32.32		
0.63		9.00	0.98	15.96	1.33	23.70	1.68	32.07		
0.62		8.82	0.97	15.75	1.32	23.47	1.67	31.82		
0.61		8.63	0.96	15.54	1.31	23.24	1.66	31.57		
0.60		8.45	0.95	15.33	1.30	23.01	1.65	31.32	2.00	40.18
0.59		8.27	0.94	15.12	1.29	22.78	1.64	31.07	1.99	39.92
0.58		8.09	0.93	14.91	1.28	22.55	1.63	30.83	1.98	39.66
0.57		7.91	0.92	14.70	1.27	22.32	1.62	30.59	1.97	39.40
0.56		7.73	0.91	14.49	1.26	22.09	1.61	30.35	1.96	39.14
0.55		7.56	0.90	14.28	1.25	21.86	1.60	30.11	1.95	38.88
0.54		7.38	0.89	14.08	1.24	21.64	1.59	29.87	1.94	38.62
0.53		7.20	0.88	13.87	1.23	21.42	1.58	29.63	1.93	38.37
0.52		7.03	0.87	13.67	1.22	21.19	1.57	29.39	1.92	38.12
0.51		6.85	0.86	13.47	1.21	20.97	1.56	29.14	1.91	37.87
0.50		6.67	0.85	13.27	1.20	20.74	1.55	28.90	1.90	37.61
0.49		6.50	0.84	13.07	1.19	20.52	1.54	28.66	1.89	37.35
0.48		6.33	0.83	12.87	1.18	20.30	1.53	28.42	1.88	37.09
0.47		6.16	0.82	12.67	1.17	20.08	1.52	28.17	1.87	36.84
0.46		5.99	0.81	12.47	1.16	19.85	1.51	27.93	1.86	36.59
0.45		5.82	0.80	12.27	1.15	19.63	1.50	27.68	1.85	36.33
0.44		5.65	0.79	12.07	1.14	19.41	1.49	27.45	1.84	35.07
0.43		5.48	0.78	11.87	1.13	19.19	1.48	27.21	1.83	35.81
0.42		5.32	0.77	11.68	1.12	18.97	1.47	26.97	1.82	35.55
0.41		5.16	0.76	11.48	1.11	18.75	1.46	26.73	1.81	35.30
0.40		5.00	0.75	11.28	1.10	18.53	1.45	26.49	1.80	35.05
0.39		4.84	0.74	11.09	1.09	18.31	1.44	26.26	1.79	34.80
0.38		4.68	0.73	10.89	1.08	18.09	1.43	26.03	1.78	34.55
0.37		4.52	0.72	10.70	1.07	17.88	1.42	25.79	1.77	34.30
0.36		4.36	0.71	10.51	1.06	17.66	1.41	25.56	1.76	34.05
0.35		4.21	0.70	10.32	1.05	17.45	1.40	25.32	1.75	33.80
0.34		4.07	0.69	10.13	1.04	17.23	1.39	25.09	1.74	33.55
0.33		3.91	0.68	9.95	1.03	17.02	1.38	24.86	1.73	33.30
0.32		3.76	0.67	9.76	1.02	16.80	1.37	24.63	1.72	33.06
0.31		3.60	0.66	9.57	1.01	16.59	1.36	24.39	1.71	32.82
0.30		3.45	0.65	9.38	1.00	16.38	1.35	24.16	1.70	32.58

Figure 34. Rating curve for structure with blocks and weir plate.

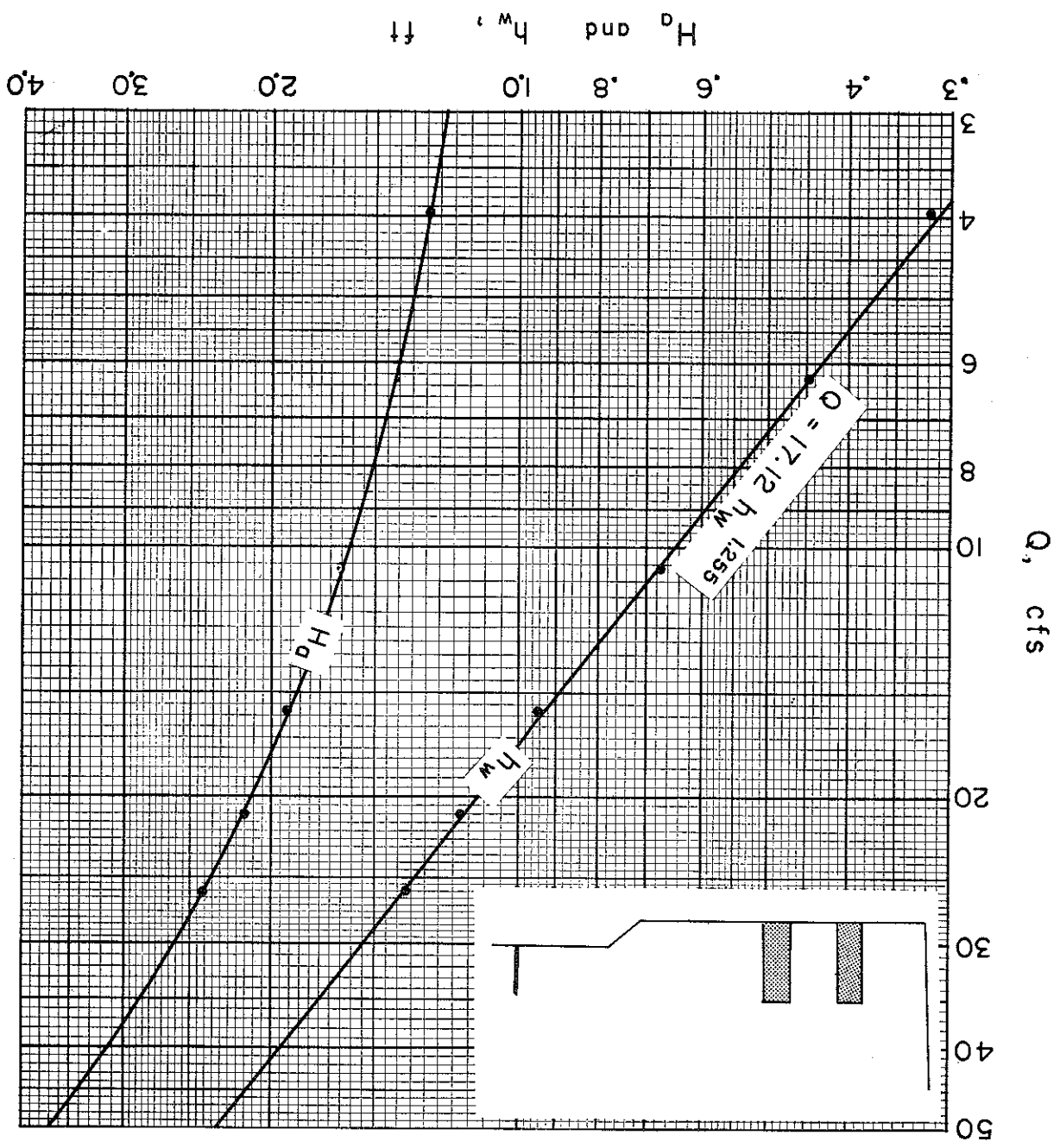
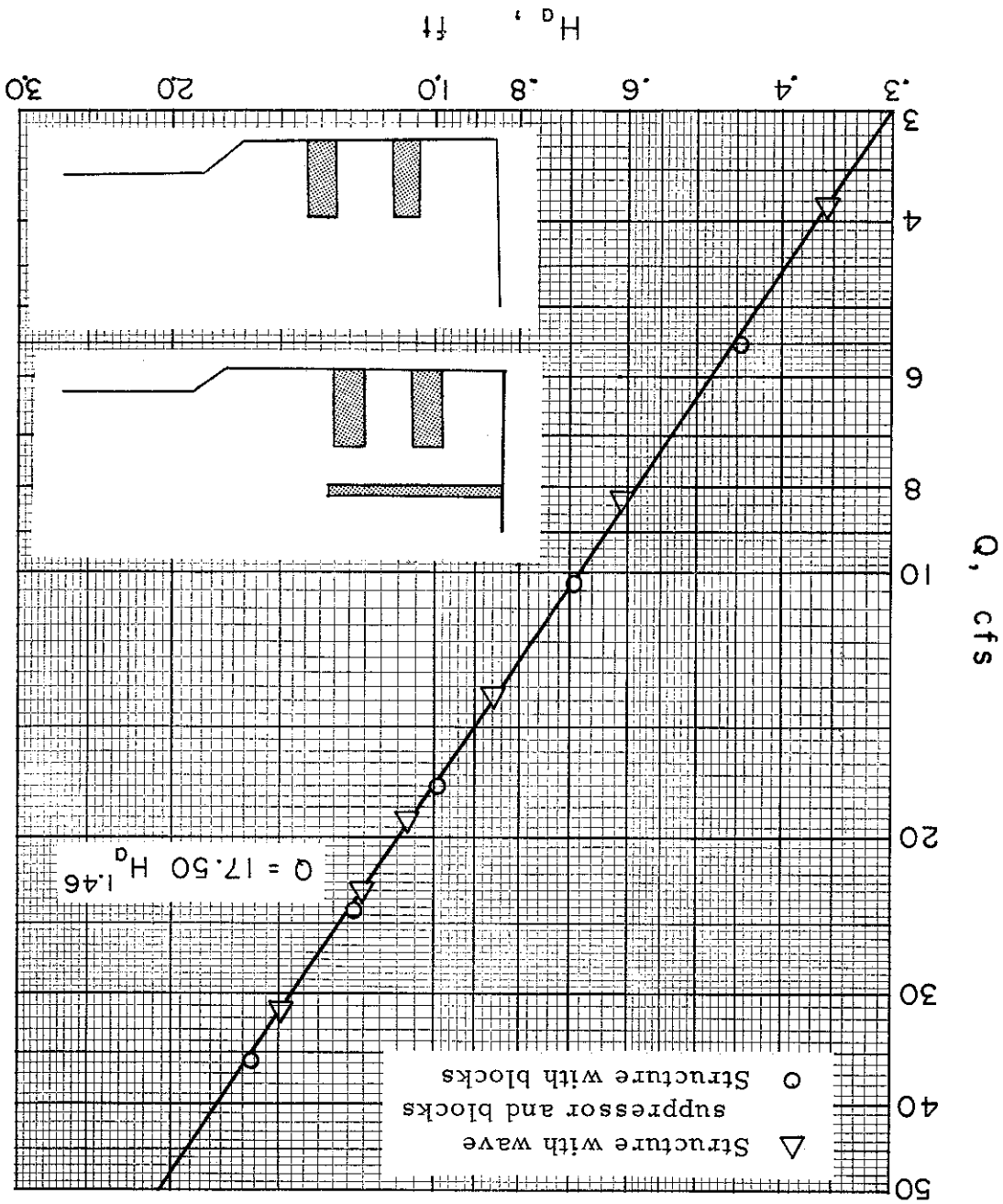


Table 2. Rating with blocks and weir plate.

h^w	0.30	3.78	0.65	9.96	1.00	17.12	1.35	24.96	1.70	33.34	1.71	33.59	1.72	33.83	1.73	34.08	1.74	34.33	1.75	34.58	1.76	34.83	1.77	35.07	1.78	35.32	1.79	35.57	1.80	35.82	1.81	36.06	1.85	37.06	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q
h^w	0.31	3.94	0.66	10.15	1.01	17.34	1.36	25.19	1.71	33.59	1.71	33.59	1.72	33.83	1.73	34.08	1.74	34.33	1.75	34.58	1.76	34.83	1.77	35.07	1.78	35.32	1.79	35.57	1.80	35.82	1.81	36.07	1.85	37.06	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q
h^w	0.32	4.10	0.67	10.35	1.02	17.56	1.37	25.42	1.72	33.83	1.72	33.83	1.73	34.08	1.74	34.33	1.75	34.58	1.76	34.83	1.77	35.07	1.78	35.32	1.79	35.57	1.80	35.82	1.81	36.07	1.82	36.32	1.85	37.06	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q
h^w	0.33	4.26	0.68	10.55	1.03	17.77	1.38	25.65	1.73	34.08	1.73	34.08	1.74	34.33	1.75	34.58	1.76	34.83	1.77	35.07	1.78	35.32	1.79	35.57	1.80	35.82	1.81	36.07	1.82	36.32	1.83	36.56	1.85	37.06	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q
h^w	0.34	4.42	0.69	10.75	1.04	17.99	1.39	25.88	1.74	34.33	1.74	34.33	1.75	34.58	1.76	34.83	1.77	35.07	1.78	35.32	1.79	35.57	1.80	35.82	1.81	36.07	1.82	36.32	1.83	36.56	1.84	36.81	1.85	37.06	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q
h^w	0.35	4.58	0.70	10.95	1.05	18.21	1.40	26.12	1.75	34.58	1.75	34.58	1.76	34.83	1.77	35.07	1.78	35.32	1.79	35.57	1.80	35.82	1.81	36.07	1.82	36.32	1.83	36.56	1.84	36.81	1.85	37.06	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q		
h^w	0.36	4.74	0.71	11.15	1.06	18.45	1.41	26.35	1.76	34.83	1.76	34.83	1.77	35.07	1.78	35.32	1.79	35.57	1.80	35.82	1.81	36.07	1.82	36.32	1.83	36.56	1.84	36.81	1.85	37.06	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q				
h^w	0.37	4.91	0.72	11.34	1.07	18.65	1.42	26.59	1.77	35.07	1.77	35.07	1.78	35.32	1.79	35.57	1.80	35.82	1.81	36.07	1.82	36.32	1.83	36.56	1.84	36.81	1.85	37.06	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q						
h^w	0.38	5.08	0.73	11.54	1.08	18.87	1.43	26.83	1.78	35.32	1.78	35.32	1.79	35.57	1.80	35.82	1.81	36.07	1.82	36.32	1.83	36.56	1.84	36.81	1.85	37.06	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q								
h^w	0.39	5.25	0.74	11.74	1.09	19.09	1.44	27.06	1.79	35.57	1.79	35.57	1.80	35.82	1.81	36.07	1.82	36.32	1.83	36.56	1.84	36.81	1.85	37.06	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q										
h^w	0.40	5.42	0.75	11.94	1.10	19.30	1.45	27.30	1.80	35.82	1.80	35.82	1.81	36.07	1.82	36.32	1.83	36.56	1.84	36.81	1.85	37.06	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q												
h^w	0.41	5.59	0.76	12.14	1.11	19.52	1.46	27.54	1.81	36.07	1.81	36.07	1.82	36.32	1.83	36.56	1.84	36.81	1.85	37.06	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q														
h^w	0.42	5.76	0.77	12.34	1.12	19.74	1.47	27.78	1.82	36.32	1.82	36.32	1.83	36.56	1.84	36.81	1.85	37.06	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q																
h^w	0.43	5.93	0.78	12.54	1.13	19.96	1.48	28.02	1.83	36.56	1.83	36.56	1.84	36.81	1.85	37.06	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q																		
h^w	0.44	6.10	0.79	12.73	1.14	20.18	1.49	28.26	1.84	36.81	1.84	36.81	1.85	37.06	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q																				
h^w	0.45	6.28	0.80	12.93	1.15	20.40	1.50	28.49	1.85	37.06	1.85	37.06	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q																						
h^w	0.46	6.46	0.81	13.13	1.16	20.62	1.51	28.73	1.86	37.31	1.86	37.31	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q																								
h^w	0.47	6.64	0.82	13.34	1.17	20.84	1.52	28.97	1.87	37.55	1.87	37.55	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q																										
h^w	0.48	6.83	0.83	13.55	1.18	21.07	1.53	29.21	1.88	37.80	1.88	37.80	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q																												
h^w	0.49	7.01	0.84	13.76	1.19	21.30	1.54	29.46	1.89	38.06	1.89	38.06	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q																														
h^w	0.50	7.18	0.85	13.96	1.20	21.53	1.55	29.68	1.90	38.32	1.90	38.32	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q																																
h^w	0.51	7.35	0.86	14.17	1.21	21.74	1.56	29.92	1.91	38.57	1.91	38.57	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q																																		
h^w	0.52	7.53	0.87	14.38	1.22	21.97	1.57	30.16	1.92	38.82	1.92	38.82	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q																																				
h^w	0.53	7.71	0.88	14.59	1.23	22.20	1.58	30.40	1.93	39.07	1.93	39.07	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q																																						
h^w	0.54	7.90	0.89	14.80	1.24	22.43	1.59	30.64	1.94	39.33	1.94	39.33	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q																																								
h^w	0.55	8.09	0.90	15.01	1.25	22.66	1.60	30.88	1.95	39.58	1.95	39.58	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q																																										
h^w	0.56	8.27	0.91	15.21	1.26	22.89	1.61	31.11	1.96	39.85	1.96	39.85	1.97	40.11	1.98	40.36	1.99	40.62	2.00	40.88	Q																																												
h^w	0.57	8.45	0.92	15.42	1.27	23.11	1.62	31.35	1.97																																																								

Figure 35. Rating curve for structure with either (1) blocks and wave suppressor or (2) blocks alone.



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should be within 2 percent. The removal of the wave suppressor has a slight effect on the location of the calibration curve (Fig. 34), but does not affect the flow measurement accuracy. The average deviation of the plotted discharge measurements from the straight line calibration curve in Fig. 34 corresponds with the average deviations in Fig. 33, about 0.75 percent. The calibration curves show, in effect, that the addition of the wave suppressor does not improve the accuracy in predicting the flow rate, but provides a smoother water surface entering the Parshall flume.

The laboratory flow rate measurements obtained with the weir plate removed are plotted in Fig. 35. A single straight line appears to be valid for the data with or without the wave suppressor. Again, it can be seen that the wave suppressor does not affect the accuracy of flow measurement. The average deviation of the plotted points in Fig. 35 from the single straight line is about 1.5 percent. Consequently, the average error in determining the discharge in the field structures can be expected to remain within 3 percent of the true discharge.

The negligible effect of the wave suppressor on flow measurement accuracy is a little surprising. More surprising to the authors was the small effect of the weir plate on flow measurement accuracy. The expected accuracy in determining discharge with the weir plate is within 2 percent as compared to 3 percent without the weir plate. The calibration curves point out the effectiveness of the blocks in dissipating the energy of the high velocity jet. A measure of effective energy

dissipation is the accuracy of the depth-discharge relationship, which is very good for any of the combinations of modifications as compared with the existing structures.

The rating curves (Figs. 33, 34, and 35) can be used for obtaining the discharge by entering the bottom of the curve with the correct upstream flow depth, moving vertically upward until the curve is intersected, and then moving horizontally to the left to read the discharge value. Figs. 33 and 34 require the upstream flow depth to be the depth of water above the weir crest measured in the stilling well and is denoted by h^w . Should the weir plate be removed, Fig. 35 would be required to determine the discharge and the standard

Parshall gage reading, H_a , would be used. The upstream flow depth, H_a , is the depth of the water in the stilling well measured above the Parshall flume crest.

Rating tables (Tables 1, 2, and 3) provide a direct method of obtaining the discharge for any of the combinations of modifications. By measuring the proper upstream flow depth, h^w , or H_a , enter the table corresponding to the modifications existing in the turnout structure with the measured flow depth and obtain the discharge.